# Ecosystem Modeling in Cobscook Bay, Maine: A Collaborative Research Project


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**The Collaboration:** In the mid-1990s an interdisciplinary, multi-institutional team of scientists was assembled to address basic issues concerning the unique co-occurrence of many unusual ecological features in Cobscook Bay, Maine. This collaborative research project was funded by a grant from the A.W. Mellon Foundation to The Nature Conservancy with matching funds and services provided by Bigelow Laboratory for Ocean Sciences, USEPA, Office of Research and Development, NHEERL, AED, University of Maine at Orono and Machias, Texas A&M University, U.S. Fish and Wildlife Service, Suffolk University (Friedman Field Station), Gulf of Maine Project, Maine Department of Marine Resources and The Nature Conservancy.

**The Study:** Cobscook Bay is a geologically complex macro-tidal system (mean tidal range 6 m) located on the international border between the United States and Canada at the mouth of the Bay of Fundy. The fieldwork reported in this poster was carried out during 1995 and 1996. Data on unstudied ecosystem components was assembled from the literature and covers the period from the late-forties to mid-nineties.

**Scientific Approach:** The strategy adopted by the scientific team was to synthesize the known information on Cobscook Bay, to focus new field research on the estuary's forcing functions and primary production and to evaluate the flows of energy and materials through the ecosystem and relate them to the inflows of physical energy by constructing an energy systems model of the estuary.

**Summary of Findings**:

Cobscook Bay is a naturally eutrophic system with high nutrient levels deriving from up-welled, nutrient-rich, Gulf of Maine waters rather than from natural or human activities in the watershed.

The largest part of the organizing emergy is supplied by the energy of the tides and waves.

Primary productivity, a third of which is exported, is dominated by benthic microphytes and brown macroalgae. Phytoplankton production is controlled by temperature and light rather than nutrients.

There is an extraordinary convergence of physical energies in the Bay and as a result primary production ranges from moderate to large depending on the requirements for the different kinds of vegetation. Because most physical inputs are present in excess, plants in the Bay transform the energy inflows into biomass less efficiently than expected, as indicated by emergy measures.

The additional emergy goes into creating rare and unusual physical, geological, and biological structures in the environment. Many of these unique features of the Bay are derived from processes using the energy in its large tides. For example, tidal mixing cools the surface waters in summer resulting in an extremely foggy environment that protects intertidal creatures from desiccation and supports the development of a diverse and sometimes giant intertidal fauna; swift tidal currents account for rare hydrologic features such as reversing falls (see photo) and whirlpools, and scour has produced an unusually large expanse of hard bottom in the central channels of the estuary; a large tidal exchange volume and strong vertical mixing result in high nitrate concentrations in the estuary for most of the year.

The transformity of trophic pathways approaches the expected values as energy moves up the food chain. The high diversity found in some environments of Cobscook Bay, *e.g.*, the intertidal, can be attributed to the extraordinary convergence of emergies in quantities that produce ideal conditions for supporting the development of ecological organization there.

## Elements of the Research

### 1. Remote Sensing and the Characterization of Habitat Areas

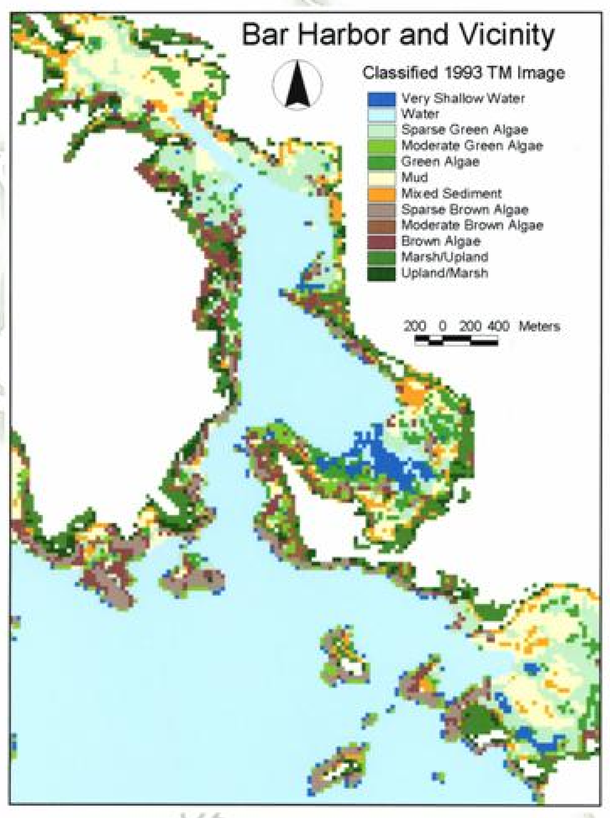



Table 3. Areas used to determine net primary production, NPP, and other ecosystem flows based on classification of remote sensed data (Larsen et al. 2004).

| Item | Area, ha |
|---|---|
| Area of estuary | 10,751 |
| Intertidal area | 3,584 |
| NPP for phytoplankton | 8,959 |
| NPP for benthic microalgae | 5,629 |
| NPP for macroalgae, kelp | 96 |
| NPP for macroalgae, fucoid | 995 |
| NPP for macroalgae, greens | 916 |
| NPP for macroalgae, reds | 212 |
| NPP for eelgrass | 186 |
| Detritus pool & bacteria | 8,959 |
| Zooplankton | 8,959 |
| Benthic Macrofauna | 4480 |
| Fish | 1810 |
| Eagles | 10,360 |
| Seals | 10,360 |
| Commercial fish | 7,167 |
| Commercial shellfish | 4480 |

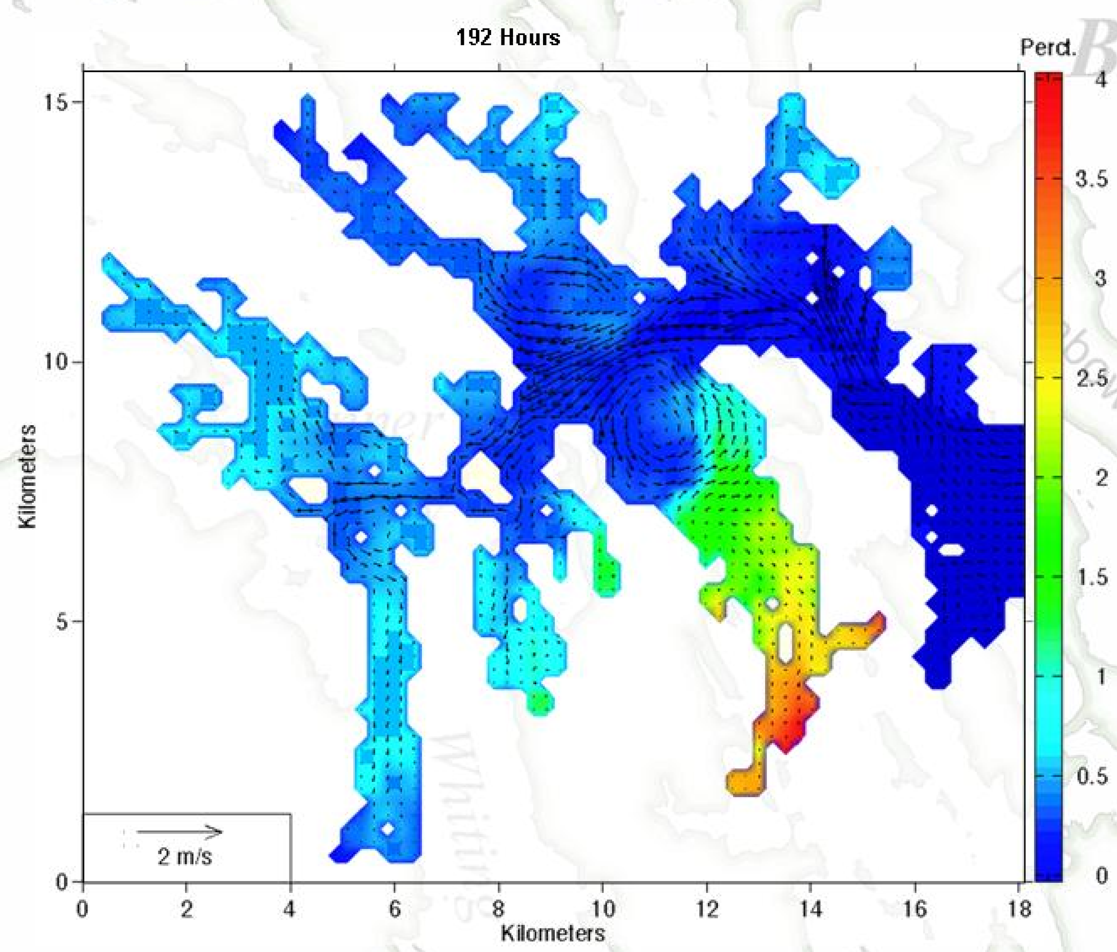
### 2. Water Quality

Fluxes of nutrients and phytoplankton into or out of the Bay as determined from the data on water quality.

Table 7. Import(+) and export (-) balance for materials moving across the Eastport to Lubec transect on the sample dates in 1995.

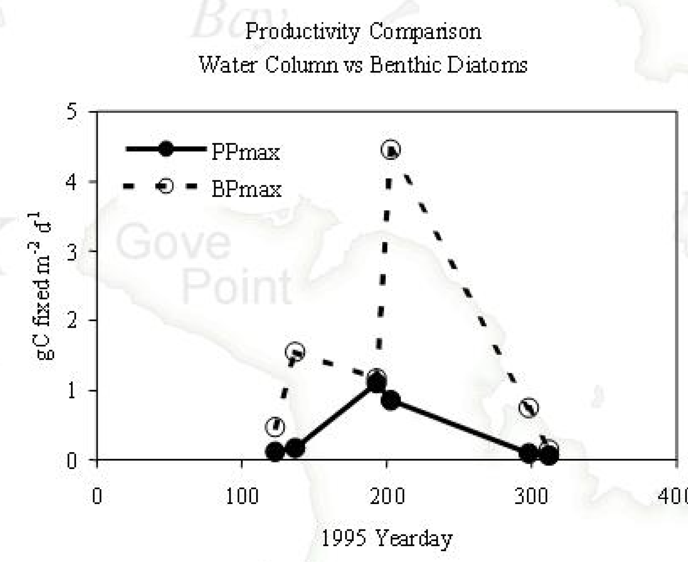
| Date | $NO_3$ gN $d^{-1}$ | $NH_4$ gN $d^{-1}$ | $PO_4$ gP $d^{-1}$ | $SiO_3$ gSi $d^{-1}$ | Phyto C gC $d^{-1}$ |
|---|---|---|---|---|---|
| May 2,3,4 | 1.0E7 | 1.6E6 | -4.3E5 | 1.0E7 | -2.7E6 |
| July 11,12,13 | 4.2E6 | 8.9E6 | -1.5E6 | -1.1E7 | 9.8E6 |
| July 21,22,32 | 4.4E6 | 1.2E7 | -3.0E6 | 1.3E7 | 3.2E7 |
| October 24,25,26 | -3.0E7 | -3.9E5 | -8.2E6 | -5.5E7 | -1.1E7 |
| November 7,8,9 | 5.0E6 | -4.8E6 | 1.1E6 | -2.2E7 | -7.8E6 |

### 3. Hydrodynamic Modeling




The percent residual concentration of a neutral tracer near the bottom 7 days after a surface source located between Birch and Gove Points was turned off. The source with a concentration of 100 units was "on" for one day (two tidal cycles). The highest tracer concentration remaining after a week of tidal flushing is a few percent in the southern end of South Bay, a region known for a rich scallop fishery.

### 4. Productivity of Phytoplankton and Benthic Microphytes




### 5. Macroalgal and Eelgrass Productivity

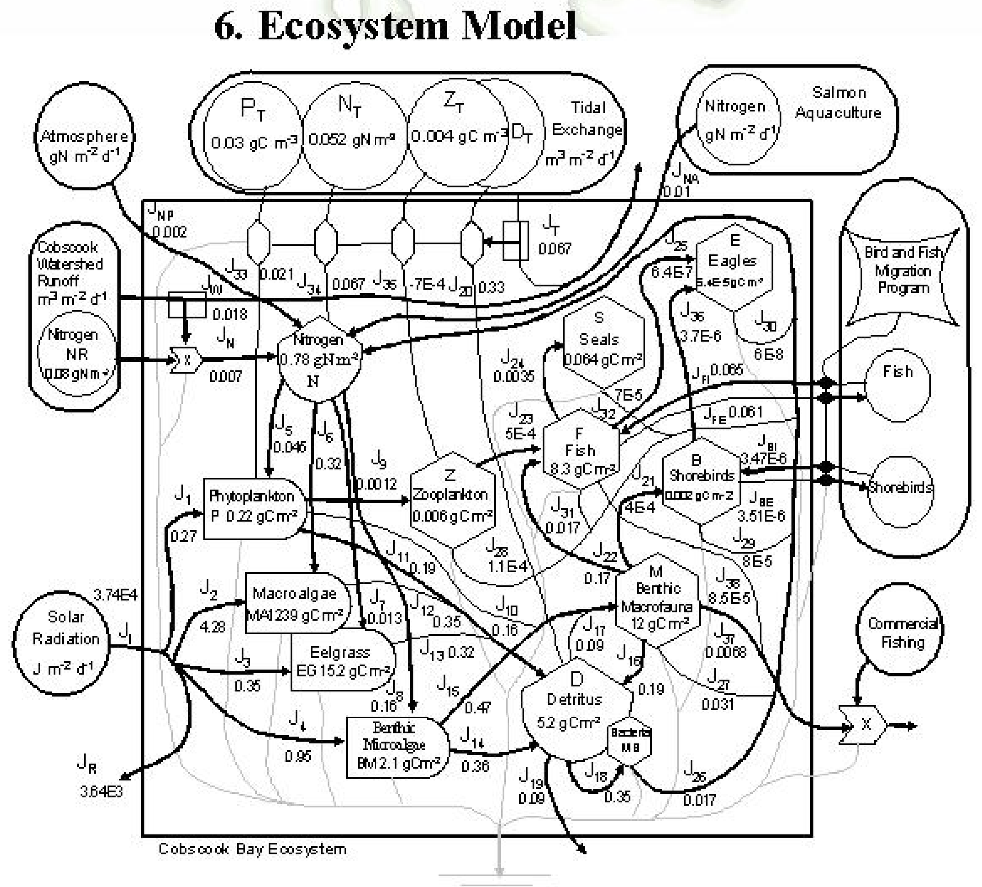
Table 6. Annual primary production in Cobscook Bay and its possible fate.

| Producer | Primary Production kg C $y^{-1}$ x $10^6$ | Consumer | Annual Consumption kg C $y^{-1}$ x $10^6$ |
|---|---|---|---|
| Phytoplankton | 8.80 | Zooplankton grazing | 0.05 |
| Benthic diatoms | 19.50 | Benthic filter feeders | 10.1 |
| Eelgrass | 0.24 | Grazing on macro algae | 0.9 |
| Fucoid algae | 6.25 | Detritus filtered | 1.5 |
| Green algae | 1.11 | Detritus, direct deposit[2] | 12.1 |
| Kelp | 0.46 | Detritus, total deposited | 15.2 |
| Red algae | 0.78 | Detritus export[3] | 12.5 |
| Total production[3] | 37.14 | Total consumption[4] | 12.6 |
| Detritus production[1] | 26.00 | | |

Reversing falls at Pembroke

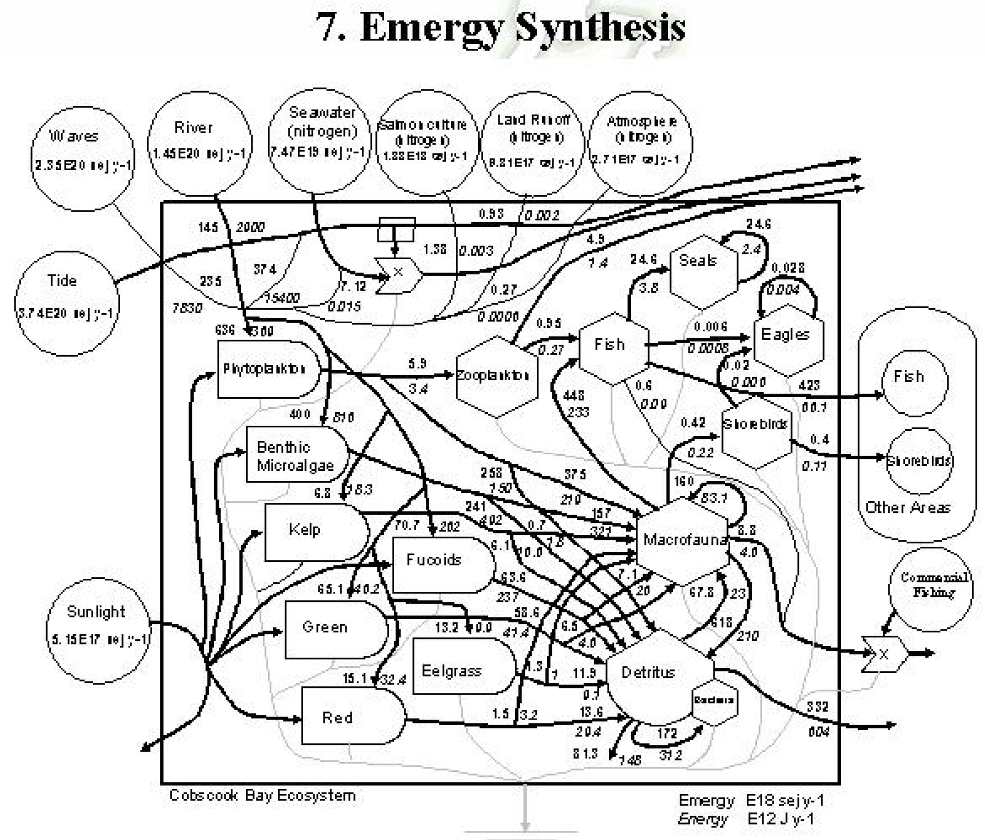
Intertidal Green Algae

### 6. Ecosystem Model




The carbon and nitrogen storages and flows in the Cobscook Bay ecosystem were evaluated as shown.

### 7. Emergy Synthesis



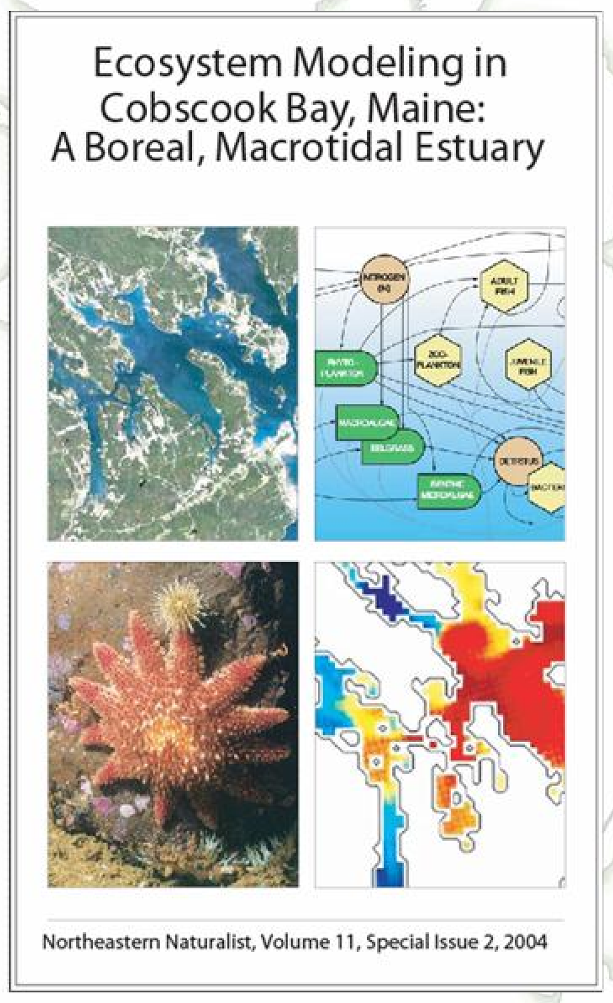

The available energy or exergy flowing on each pathway is shown along with the solar emergy required. The transformity of the pathway is the ratio of the solar emergy required to the flux of available energy.

**Significance of the Collaboration:** This project was one of the first scientific research projects to be funded by the Maine Nature Conservancy. By studying a whole system we obtain a deeper and more profound understanding of the structure and function of that place and how it fits into the larger world. Information is the key to making good decisions for land purchase and for the future well-being of humanity and nature.

Systems studies like this one cannot be done alone; they require the expertise of many diverse scientists and stakeholders, as well as the backing of both nongovernmental and governmental organizations. Most of all collaborations require that all the members of the group believe in the project and be willing to make sacrifices to see it through to completion. We were fortunate to have such a group working on the Cobscook Bay project.

It is our hope that this project and others like it will contribute to a better understanding of the energy basis for the ecological organization of natural and human systems and that in turn our greater knowledge will lead to better decision-making

**The Product:**





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